Journal of the Royal Society of Arts

NO. 4997 FRIDAY, 15TH FEBRUARY, 1957 VOL. CV

FORTHCOMING MEETINGS

MONDAY, 18TH FEBRUARY, at 6 p.m. The first of three CANTOR LECTURES on '*The Contribution of Lighting to Modern Life*', entitled '*Lighting in Outdoor Life and Work*', by J. M. Waldram, B.Sc., F.I.E.S., A.M.I.E.E. (The lecture will be illustrated with a film, lantern slides and exhibits.)

WEDNESDAY, 20TH FEBRUARY, at 2.30 p.m. '*Modern Detergents*', by F. Courtney Harwood, B.Sc., F.R.I.C., M.I.Chem.E., F.T.I., F.S.D.C., lately Director, British Launderers' Research Association. Sir Eric Rideal, M.B.E., M.A., Ph.D., D.Sc., F.R.S., will preside. (The paper will be illustrated with lantern slides.)

MONDAY, 25TH FEBRUARY, at 6 p.m. The second of three CANTOR LECTURES on '*The Contribution of Lighting to Modern Life*', entitled '*Lighting in Commerce and Industry*', by C. Dykes Brown, A.M.I.E.E., F.I.E.S. (The lecture will be illustrated with lantern slides and demonstrations.)

WEDNESDAY, 27TH FEBRUARY, at 2.30 p.m. '*Synthetic Detergents—A New Pollution Problem*', by B. A. Southgate, C.B.E., Ph.D., D.Sc., F.R.I.C., Director, Water Pollution Research, D.S.I.R. Sir Eric Rideal, M.B.E., M.A., Ph.D., D.Sc., F.R.S., will preside. (The paper will be illustrated with lantern slides.)

MONDAY, 4TH MARCH, at 6 p.m. The last of three CANTOR LECTURES *and Architecture*', by D. W. Durrant. (The lecture will be illustrated with lantern slides and demonstrations.)

WEDNESDAY, 6TH MARCH, at 2.30 p.m. FERNHURST LECTURE. '*Trace Elements in Plant Nutrition: with special reference to crops*', by T. Wallace, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S., Professor of Horticultural Chemistry, University of Bristol, and Director, Long Ashton Research Station. Sir William Slater, K.B.E., D.Sc., F.R.I.C., Secretary, Agricultural Research Council, will preside. (The lecture will be illustrated by lantern slides.)

THURSDAY, 7TH MARCH, at 5.15 p.m. COMMONWEALTH SECTION. '*The Arts in Australia*', by D. J. Finley, Films and Exhibitions Officer, Office of the High Commissioner for Australia in London. (Tea will be served from 4.30 p.m.)

WEDNESDAY, 13TH MARCH, at 2.30 p.m. '*The Air Training Corps—its History and Place in Contemporary Society*', by Wing Commander Norman Macmillan, O.B.E., M.C., A.F.C., D.L., A.F.R.Ae.S. Christopher Soames, C.B.E., M.P., Parliamentary Under-Secretary of State, Admiralty, will preside. (The lecture will be illustrated by lantern slides.)

Fellows are entitled to attend any of the Society's meetings without tickets (except where otherwise stated), and may also bring two guests. When they cannot accompany their guests, Fellows may give them special passes, books of which can be obtained on application to the Secretary.

THE ALBERT MEDAL

The Council are now considering the award of the Albert Medal of the Royal Society of Arts for 1957. They therefore invite Fellows of the Society to forward to the Secretary as soon as possible the names of such men of high distinction as they think worthy of this honour. The Medal was struck to reward 'distinguished merit in promoting the Arts, Manufactures and Commerce', and has been awarded as follows in previous years:

1864	Sir Rowland Hill
1865	His Imperial Majesty NapoleonIII
1866	Michael Faraday
1867	Sir W. Fothergill Cooke and Sir Charles Wheatstone
1868	Sir Joseph Whitworth
1869	Baron Justus von Liebig
1870	Vicomte Ferdinand de Lesseps
1871	Sir Henry Cole
1872	Sir Henry Bessemer
1873	Michel Eugène Chevreul
1874	Sir C. W. Siemens
1875	Michel Chevalier
1876	Sir George B. Airy
1877	Jean Baptiste Dumas
1878	Sir Wm. G. (afterwards Lord) Armstrong
1879	Sir William Thomson (afterwards Lord Kelvin)
1880	James Prescott Joule
1881	Prof. August Wilhelm Hofmann
1882	Louis Pasteur
1883	Sir Joseph Dalton Hooker
1884	Captain James Buchanan Eads
1885	Sir Henry Doulton
1886	Samuel Cunliffe Lister (afterwards Lord Masham)
1887	HER MAJESTY QUEEN VICTORIA
1888	Professor Hermann Louis Helmholtz
1889	John Percy
1890	Sir William Henry Perkin
1891	Sir Frederick Abel, Bt.
1892	Thomas Alva Edison
1893	Sir John Bennet Lawes, Bt., and Sir Henry Gilbert
1894	Sir Joseph (afterwards Lord) Lister
1895	Sir Isaac Lowthian Bell, Bt.
1896	Professor David Edward Hughes
1897	George James Simons
1898	Professor Robert Wilhelm Bunsen
1899	Sir William Crookes
1900	Henry Wilde
1901	HIS MAJESTY KING EDWARD VII
1902	Professor Alexander Graham Bell
1903	Sir Charles Augustus Hartley
1904	Walter Crane

1905 Lord Rayleigh
1906 Sir Joseph Wilson Swan
1907 The Earl of Cromer
1908 Sir James Dewar
1909 Sir Andrew Noble
1910 Madame Curie
1911 The Hon. Sir Charles Algernon Parsons
1912 Lord Strathcona and Mount Royal
1913 HIS MAJESTY KING GEORGE V
1914 Senatore (afterwards Marchese) Guglielmo Marconi
1915 Sir Joseph John Thomson
1916 Professor Elias Metchnikoff
1917 Orville Wright
1918 Sir Richard Tetley Glazebrook
1919 Sir Oliver Joseph Lodge
1920 Professor Albert Abraham Michelson
1921 Sir J. Ambrose Fleming
1922 Sir Dugald Clerk
1923 Major-General Sir David Bruce and Colonel Sir Ronald Ross
1924 H.R.H. THE PRINCE OF WALES
1925 Lieut.-Colonel Sir David Prain
1926 Professor Paul Sabatier
1927 Sir Aston Webb
1928 Sir Ernest (afterwards Lord) Rutherford
1929 Sir J. Alfred Ewing
1930 Professor Henry E. Armstrong
1931 H.R.H. THE DUKE OF CONNAUGHT AND STRATHEARN
1932 Frank (afterwards Sir Frank) Brangwyn
1933 Sir William Llewellyn
1934 Sir Frederick Gowland Hopkins
1935 Sir Robert A. Hadfield, Bt.
1936 The Earl of Derby
1937 Lord (now Viscount) Nuffield
1938 HER MAJESTY QUEEN MARY
1939 Sir Thomas H. Holland
1940 John A. Milne
1941 President Franklin D. Roosevelt
1942 Field-Marshal J. C. Smuts
1943 Sir John Russell
1944 Sir Henry Tizard
1945 Winston (now Sir Winston) Churchill
1946 Sir Alexander Fleming and Sir Howard Florey
1947 Sir Robert Robinson
1948 Sir William Reid Dick
1949 Sir Giles Gilbert Scott
1950 Sir Edward Appleton
1951 HIS MAJESTY KING GEORGE VI
1952 Sir Frank Whittle
1953 Dr. E. D. (now Lord) Adrian
1954 Sir Ambrose Heal
1955 Dr. Vaughan Williams
1956 Sir Henry Dale

JOURNAL BINDING CASES

As already announced in the *Journal*, the binding cases have been redesigned to bear a family resemblance to the new *Journal* cover. The cases for volume 104 are now available and should be obtained direct from the Society's bookbinders, Messrs. P. G. Chapman & Co., Ltd., Kent House Lane, Beckenham, Kent, at a cost of 7*s*., post free. An index and title page will be included.

Messrs. Chapman are also prepared to undertake binding, at an additional cost.

ENGINEERING ELECTRONICS

Three Cantor Lectures

ON THE TECHNICAL AND INDUSTRIAL ASPECTS OF ELECTRONICS, EXCLUDING RADAR AND SERVICE EQUIPMENT

by

L. E. C. HUGHES, A.C.G.I., D.I.C., B.Sc.(Eng.), Ph.D., M.I.E.E.

I. RADIATION

Monday, 26th November, 1956

ORIGINS

The Greeks had a word for amber and that was *electron*, and they knew that rubbing amber gives rise to attractive forces; the material thus gave the name to the unknown cause rather than to the effect. Little more seemed to be recorded until Gilbert used the word 'Electricity' in 1600, but Dr. Johnson in his dictionary first quotes Newton's *Optiks*:

> If a piece of paper or a white cloth, or the end of one's finger be held at a quarter inch from the glass, the electric vapour, excited by friction, will by dashing against the white paper, cloth, or finger, be put into such an agitation as to emit light,

and then goes on to say:

> . . . Bodies electrified by a sphere of glass, turned nimbly round, not only emit flame, but may be fitted with such a quantity of electrical vapour as, if discharged at once upon a human body, would endanger life. The force of this vapour has hitherto appeared instantaneous, persons at both ends of a long chain seeming to be struck at once. The philosophers are now endeavouring to intercept the strokes of lightning.

This presumably includes a reference to one whom we are always glad to remember in the Society, Benjamin Franklin, who fortunately did not meet the fate which his experiments would prompt us to be certain of to-day. In his day there were two kinds of electricity, which were recognized to neutralize each other, so he labelled them positive and negative. We are grateful for this nomenclature, but he inadvertently got it the wrong way round. Because all electrical current is the motion of electrons, negative electrical charges, we have the necessity of explaining to students that current really goes the wrong way round circuits. I know of only one American text-book which in its circuits indicates the correct direction of the electrons which give rise to the phenomena described; it is by Fink, who anticipated the title of these lectures. No one as yet has successfully followed up Benjamin Franklin's idea of obtaining a vast

amount of electrical power from thunderclouds, and it would probably not be much use if we could, because we have no means of storing electrical power as such on industrial scale.

In history the next great advance was the discovery by Galvani of the electrolytic cell, which can generate electric power by using certain chemicals. The (nearly) dry pile of Galvani cells in series is used at the present time for charging electroscopes, and will probably be used for charging the pocket dosimeters, used in radiation laboratories, in hospitals and in Civil Defence for registering doses received since last charged.

During the last century a scientist was hardly respectable if he did not produce a new type of primary or secondary cell; although few of these became commercial, there is still ample scope for new cells. Before the war the Drumm accumulator was used to drive Irish trains, and during the war a great improvement in the ordinary so-called dry Leclanché cell was achieved by using mercury as a depolarizer and now has a widespread use. This Mallory cell, little larger than a pea, has made possible hearing-aids which comprise a complete transistor amplifier in the side-frames of spectacles. Recently a new and tiny accumulator of high discharge rating has been produced, of considerable use in expendable electronic equipment. The sea-cell, using inert electrodes until immersed in sea-water and often written about, has obvious advantages in providing small electrical power for rescue work at sea.

LIGHTING

The next major step in electronic history seems the electric arc, and we read of Faraday's difficulties at the Royal Institution in getting adequate batteries for studying the phenomenon which, when developed for public use, formed the first purely electronic device to be exploited on a large scale. In the arc, the action is started by passing a current through two carbon (or metal) rods in contact. This heats the contact, and thermal electrons are released from the negative carbon; their impact on the positive carbon is so great that carbon is vapourized and ionized in the gap, giving both positive and negative ions. On pulling the carbons apart the impact of these ions on their opposite carbons releases enough heat to keep the reaction going and so set up intense light sources at ends of the carbons, which burn away.

In the early days of this century arc-lamps were widespread, in streets, shops, railway stations and yards, and factories. These have all gone, and only now remain as the essential component in large searchlights and large cinema projectors; this is because the arcs drawn between carbons, augmented by admixture of cerium, have a sufficiently high intrinsic brilliance, rivalled only by the sun and mercury arcs under pressure, to be controlled with precision, optically. Modern lighting cannot tolerate this high source concentration, apart from the economy of the newer electronic sources.

Even 100 years ago there were electric discharges in rarified gases and the Geissler tube is but the primitive from which has grown the dominant form of illumination to-day. Then a discharge was entirely a scientific phenomenon,

[*By courtesy of Ionlite Ltd., London*

FIGURE 1. *High-voltage fluorescent advertisements in Oxford Street, London. The large display is in blue, pink, green, off-white, warm-white, ruby and opal red. It is rated at 22 kW., with 3,300 feet of tubing, there being one mile of high tension wiring and 3·75 miles of low-tension wiring and conduit*

made of use only in the constricted discharge useful in calibrating spectrometers with known wavelengths. The discharge could not be made either efficient or effective.

It was discovered that mercury vapour could be made to give a characteristic blue light, and long tubes were used to some extent for public illumination, with scant regard to eyesight. After the First World War it was found that some

gases, neon, hydrogen, xenon, were effective in themselves and by 1930 'neons' of all colours were widespread and now saturate our streets, but only if they have advertising value. For strictly utilitarian usage the sodium vapour lamp introduced from the Continent in the early 1930s, made rapid progress, and at the present time these lamps, if traffic considerations dominate, are the only ones possible for new installations, apart from special installations to mitigate the effect of fog. Until the past few years they did not make their full impact, perhaps because of the challenge of the corrected mercury-vapour lamp, but there is now no doubt of their utilitarian value. They are actually being used for illuminating constructional work, as in the City of London.

The very virtue of sodium lighting, monochromatic radiation, has called forth protests on artistic grounds, and the concrete standards have also invited severe criticism.

FIGURE 2. *Old and new in lighting, showing a sodium vapour electronic discharge lamp for side streets installed at Kew Green. There have been protests there, in Richmond and St. John's Wood respecting the concrete standards, which are economical in that no painting is required*

The most brilliant display of sodium vapour lighting is in Bayswater Road, and no one could remain unconvinced of its value on leaving this stretch and plunging into the gloom of tungsten filament lighting towards Notting Hill Gate. Incidentally, Bayswater Road was the last outpost of the most effective usage of gas for street lighting, high-pressure gas with inverted mantles.

It was not until about 1930 that careful experiments showed us we could not really illuminate objects on the road at all, at least economically; we do not 'see' distant objects at night, only their silhouettes; and colour, at these levels of illumination, does not help. The enhanced acuity with sodium lighting arises from the monochromatic radiation, which requires the eyes to focus the outlines of distant objects for one wavelength only and not a wide spread of wavelengths,

as with corrected mercury lighting. For the same reason many road signs are printed black on yellow. The geometry of the lamps makes for difficulties in designing the standards which have to support them at proper heights and these too have been villified.

The outstanding advance, just before the Second World War, was the introduction of fluorescent powders to be excited by a discharge through mercury vapour, prompted no doubt by the use of these powders for cathode-ray tube screens during the previous twenty years for measurements and later for television. The mercury discharge radiates ultra-violet rays, and these excite longer wave radiations from the internally deposited powders. Many pastel colours are available, but it is only recently that a good signal red has been achieved, helped by a red glass tube. Apart from mere economy, the low intrinsic brightness of the tubes permits them to be used without protection indoors. In factories, offices and many public buildings no other form of illumination would be considered to-day. A magnificent example of tubular fluorescent lighting is in the giant BOAC maintenance hanger at London Airport, where there are no windows at all and near-daylight conditions are perpetual. Indeed, where traffic considerations have to be tempered in places much frequented by the public, the long fluorescent tube is making inroads. There are masses of vertical tubes in the City streets, and in shopping districts, such as Brompton Road and Marylebone Road, horizontal tubes are becoming prominent.

There are at present two forms of tubular lighting. There are long thin tubes in which the voltage has to be high enough for electrons from cold electrodes to ionize the mercury gas and the radiation therefrom to excite the radiation from the powder. This is the type used for large advertisements, and for cinema-foyer and restaurant lighting, with great effect. The shorter tube of wider diameter uses filaments at each end to supply electrons. For starting, these filaments are heated until the discharge starts, after which the impact of the discharge keeps a spot on the filament alight; this spot progresses along the coated filament and when there is no coating left the tube has reached the end of its life. These tubes should not be switched often, because this shortens the life of the filaments. They normally operate on low-voltage alternating current; if on direct current supply, a pole-changing switch must be used. Such tubular lamps are in use in at least one aircraft carrier and on the royal yacht Britannia. In a recent year 100 million such tubes were made in the United States.

Because of rapid response and exceedingly long life, discharge tubes make excellent flashers, for instance for lighthouses and police beacons. By making use of the persistence of vision and a very short flash a considerable range of several miles can be obtained from dry cells, with renewals only after intervals of months. Crude flashing switchers can be made with bimetal strips, but more refined flashers use a self-operating circular pendulum which induces a high voltage.

On a much smaller scale, but nevertheless intrinsically important, there have been diverse radiation developments, both for medicine and for industry. In the latter special illuminations can be used for colour matching, for chemical

reactions, while in the former special radiations have been used for curative purposes for half a century. The largest possibly in application has been in ultra-violet from carbon-arcs and mercury vapour tubes for children. Such rays are dangerous and treatment should be supervised; there are, however, harmless discharge tubes which effect a tanning of the skin of only cosmetic importance. In fact, tanning should not take place in medical treatment, because that is nature's way of partial protection. A real overdose of ultra-violet rays can be fatal, if not only uncomfortable through burning.

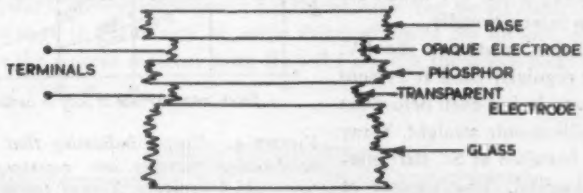


FIGURE 3. *New source of light. Current is passed between the terminals and excites fluorescence in the phosphor between the electrodes*

Are there likely to be new forms of lighting in the future? Can we rival the efficiency of the light from the beetle called the glow-worm? There are powders which emit light according to temperature, so it is a simple matter to make a flat unit which carries a layer of powder between two plates, one of which is transparent, carrying the heating current. But to turn what is a scientific novelty into a commercial commodity is another story. It has likewise been shown that a light amplifier is possible, an image falling on one side of a composite plate being more brilliant on the other side. The radiating paint, widely used in advertising, which is brighter than it should be under illumination, is an excellent example of how a related scientific phenomenon can be brought into practicality.

X-RAYS

Historically the next major gift to mankind was X-rays, discovered by Röntgen about 1892. He found from a Crooke's discharge tube an uncontrollable radiation which gave silhouettes on a photographic plate, and we must be gratified to know that the technique of applying these rays to human diagnosis was soon widespread. In principle, a beam of electrons impinges on a target and emits rays from the point of impact, the energy of the rays depending on the applied voltage and their character upon the material of the target, which is usually tungsten. Tubes became more and more reliable, while Coolidge increased the flow of electrons and the intensity of the beam by using a heated filament for the electron source. Water-cooled and rotating targets have been used to facilitate removal of heat from the impact of electrons.

In hospitals the regular units are operated at fifty kV., but it should be realized that good X-ray pictures depend on how still the patient can be during

the exposure; the latter therefore should be short, which means high voltages. Exposures for photographs are of the order of one second. Continuous fluoroscopy means much longer exposures and care has to be taken that the patient does not receive excessive dosage of radiation, limits for which are laid down internationally.

For cancer treatment 200 kV. tubes are regularly used at present on a wide scale, but even before the war a million-volt straight X-ray tube was installed at St. Bartholomew's Hospital. The success of radiation treatment has led to the use of 2-million volt tubes, driven by Van de Graaff generators, which (apart from dust precipitors) remain the only outstanding use of large electrostatic machines. At the Royal Marsden Hospital the patient is adjusted on a rotating couch such that the rotation axis and the axis of the X-ray beam intersect at the point of intended treatment. This provides the maximum dose where required and the minimum possible stray dose elsewhere.

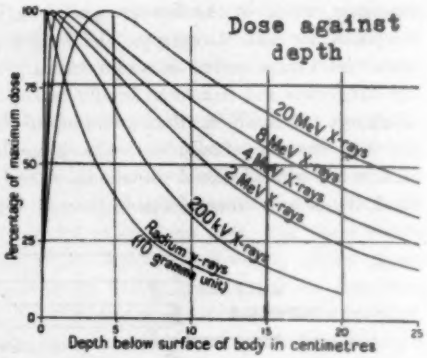
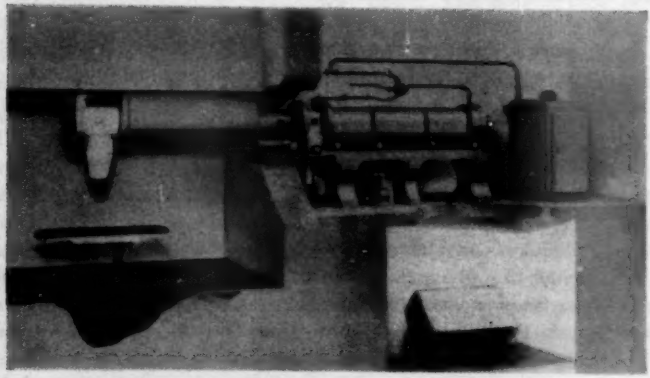


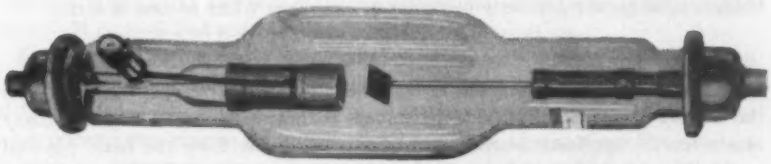
FIGURE 4. *Curves indicating that very high accelerating voltages are necessary for electrons which generate X-rays for deep therapy*



[By courtesy of Mullard Ltd.

FIGURE 5. *Photograph of model of 15-million volt linear electron accelerator being developed for therapeutic purposes. The power supply and the waveguide structures are on top right, the control desk below, and the treatment couch on the left. Such apparatus is required to give deep X-ray treatment, possibly up to 100 röntgens per minute. It is surrounded by thick concrete walls for safety*

For higher energy X-rays, the post-war novelty is the introduction of linear accelerators, otherwise used for the bombardment of elements with other particles, for example, at Harwell, for purely research purposes. There are a number of such accelerator X-ray tubes at 4 million volts. In such a tube the electrons from a thermal source are wafted through a number of diaphragms by high radio frequency voltages, much as a surf rider is carried by a wave before it breaks. For supplies, it was fortunate that radar equipment and technique was available. At their maximum velocity the electrons strike a target or are turned through a right angle to do so, the whole apparatus being supported on a giant cradle or gantry, so that the correct treatment angle can be attained. The concentrated dosage is at the rate of some thirty röntgens per minute, so that in one minute the patient receives more than the average the whole body naturally receives in a lifetime.



Length: *26 inches (660 mm)*; diameter: $5\frac{1}{8}$ *inches (130 mm)*

FIGURE 6. *Solus TX102 Flash X-ray tube. This tube is expendable and up to thirty flashes can be obtained in research work. The discharge is obtained from a Marx high-voltage source and is over in a fraction of a milli-second*

The spectacular use of X-rays as an electronic device in medical diagnosis naturally attracted the interest of industry. The critical use is the examination of castings of all kinds of metal. Castings are expensive items, but if there is an internal flaw it is obviously desirable to detect it and reject the casting before any expensive machining, revealing the flaw, is performed. There can be flaws in welds and in critical cases these should also be examined by X-rays. Before the war there were many large industrial plants for this type of work, but the main drawback is the expense of such equipment and the necessity of bringing the articles to it, as well as the practicability of doing the examination at all. Nevertheless, this is an active field of X-ray inspection, photographically.

RADIOACTIVITY

A modern competitor, in the last twenty years, to X-ray treatment for cancer was first radium, of which four grammes was a large pre-war source at the Royal Marsden Hospital, then after the war ten grammes of cobalt-60 from Canada's heavy-water nuclear reactor at Chalk River, and now, two months ago, 1,200 curies of caesium-127 from waste products from nuclear reactors in this country, with promise of vastly greater sources in future, when the nuclear power stations get going. Such a source, equivalent to more than 1,000 grammes of radium

(at £5,000 per gramme) requires nearly a ton of natural uranium and lead to protect people nearby. The Canadians have devised a Theratron so that such a source can be rotated round a patient to get the maximum differential effect.

Radioactive sources are now a great competitor to X-ray plant in industry for inspection purposes, but photographs alone can be produced. There is, however, great portability and flexibility arising from the physical smallness of the sources; these can, in fact, be placed inside castings and photographs taken on the outside. Casting and welding examination is naturally the most frequent application and no other method is possible for verifying the soundness of welds between sections of piping.

Radioactive sources are naturally dangerous and have specially designed containers for transport. Frequently the objects to be gamma-rayed are placed in a circle with the exposed source at the centre, the photographic plates in holders outside, the exposure being taken overnight when no one is about.

ELECTRO–MEDICAL

One of the most remarkable developments since the recent War has been the establishment of physical departments in hospitals, controlling the many new scientific applications and auxiliaries to medicine from the basic physical angle. The profession of hospital physicist is now well established and has its own learned society. It is concerned with X-ray apparatus and measurement, the introduction of isotope techniques both for treatment and diagnosis, electro-cardiography, electroencephalography, electro-convulsion therapy, radiations of all kinds, as well as supervising and operating the safety control for staff and patients in potential contact with harmful radiations. Nearly all the apparatus, its development and use, falls into the realm of electronics.

Most spectacular is the use of scintillation counters for the location of tumours. The Geiger-Müller counter can be made a robust and portable device, but for the detection of weak radiation and where laboratories can provide expert supervision, it has been replaced almost entirely in hospitals by the more sensitive scintillation counter. In this, incident gamma radiation in certain liquids and crystals excites minute radiation of a longer wavelength, which can release electrons from a photoelectric surface. These are accelerated towards another surface, so that on impact they emit secondary electrons in greater quantity. This process can be repeated a number of times, using electric fields to control the streams of electrons, until there is a sufficient quantity to operate a meter. The originating gamma radiation can be that which arises from radioisotopes taken in by a patient. Because iodine is particularly attracted to the thyroid gland, a radioactive isotope of iodine likewise follows, and in a short time can be detected through an external scintillation counter. Again, a radioactive isotope of arsenic, when taken, collects in the brain, and the newer cells of a tumour take it up to a higher density. Through a mechanical scanning arrangement a scintillation counter can be used to take a complete plot of the brain, and a chart recording the intensity of the gamma rays can guide the surgeons

in their exploration. Additionally, the surgeon can use such a detector on the end of a tube to find the exact location of the tumour in the brain.

MEASUREMENTS

For all purposes these radiations have to be measured, either for exposures or protection. Pierre Curie made an ionization meter for his wife, otherwise she could have made no progress in her radioactivity research. Later Geiger used the ionization of the gas in a low-pressure tube carrying a wire at high positive potential. The radiation causes separation of charges depending on its energy and the resulting movement of charge results in a Townsend avalanche of charge, which can be measured, either as a pulse or a continuous indication on a meter. These G-M counters are now easily obtainable and have given rise to weekend uranium exploration parties in various parts of the world, as well as more serious monitoring uses. Practically everyone working near a nuclear reactor or when using radioactive sources in laboratories or industry is protected by a G-M counter and must be monitored for contamination.

Because Civil Defence and rescue column personnel are much concerned with radioactive contamination arising from fall-out from A or H bombs, special types of G-M instruments have been developed for service use, and which determine when persons may emerge from shelters and how long personnel can be permitted to work in dangerous areas. These instruments will be available soon in large numbers for training purposes and a circular slide rule has been designed for speedy contamination and dosage calculations.

One may legitimately ask whether electronics has made any marked reaction on fundamental ideas other than those directly concerned with the nature of the atom. One such may be cited; the way in which we obtain our fundamental unit of measurement.

The radiation from electronic gaseous discharge has many wavelengths and the study of these has led to much of our present knowledge of atomic structure, not only of the electrons but of the nucleus, for many lines have a fine structure determined by the spin of the nucleus itself. Thus if an element has a number of isotopes those nuclei of even mass have exhibited no fine structure, while those of odd mass do. Now our scientific standard of length is determined by the wavelength of a certain red line of the cadmium used as a light source in an interferometer. It was thought that more accurate comparisons of length could be made if an atom of even nuclear mass could be used. Mercury having a suitable green line, a single isotope of mercury was made by placing some gold, which is a single isotope of mass 197, in a nuclear reactor; after some months' bombardment with neutrons the mercury isotope of mass 198 was extracted and used in a discharge tube, and being even in mass and uncontaminated with other odd isotopes gave a much sharper image, its green line having no fine structure and no consequent blurring effect. It is thus that the old alchemists' dream of making gold out of mercury has been reversed through the necessity of using an electronic device. The proposed change-over from the red cadmium line has, however, not yet taken place.

SUMMARY

This lecture has dealt briefly with radiation effects arising from electrons and how these effects are usefully employed. The visible rays arise from electrons which jump up and down through their energy levels, which define their shell deployment about their respective nuclei. These changes arise from the absorption of *quanta* of energy from incident radiation or the actual stripping of electrons by high electric fields arising from high voltages applied to electrodes. X-rays come from the innermost shells of the electrons surrounding the nucleus, while the gamma-rays come from the nucleus of the atom itself, the former from impact of high-speed electrons and the latter from the spontaneous radioactive break-down of atoms, whether natural or induced. The advent of large nuclear reactors means that there will be ample supplies of radioactive isotopes for usage by trained personnel.

It was the early investigation of this radioactive breakdown of atoms, by Rutherford and Soddy within the lifetime of many of us, that led to atomic knowledge that foreshadowed nuclear power. Electrons do not enter the subject of atomic energy, but their configuration in so-called shells determines the chemical and many physical properties of the elements; these properties have to be taken into account in realizing the new power that we have wrested from nature. It is the odd electrons which are easily detachable from the outermost shells of a small proportion of the atoms of metals that enable us to distribute all electrical power, whether derived from nuclear breakdown or not; it is now inconceivable in what other way power could be distributed from many sources to multitudinous services for mankind. Yet it is a solemn thought that the basic ideas of generation, distribution, and utilization of electric power were all laid down and made commercial before the vehicle of this transmission of power, the electron, was discovered. In a very few avenues is electronics making itself felt in power engineering, but some of these are important.

ACKNOWLEDGEMENTS

Modern fluorescent tubes were demonstrated by Mr. H. Stern of Messrs. Londex Ltd., including (*a*) neon flasher as used in police bollards, airport portable warning lamps, using dry cells which last for some months and a self-sustaining rotary pendulum interrupter; (*b*) similar designs with fluorescent powders; (*c*) one-foot fluorescent tubes, for portable lighting, using accumulators and vibrators, as in a floating flare-path for flying boats; (*d*) tungsten lamp flasher for buoys with accumulators, replaced every six months, using a night-and-day selenium (Megatron) photocell and Mumetal relay, and an accurate timing motor.

A medical film was shown, by arrangement with Philips Balham Works, which illustrated the advance available in radiographic cinematography using an X-ray intensifier.

II. CONDUCTION

Monday, 3rd December, 1956

SCOPE OF ELECTRONICS

Round about my nativity the International Electrotechnical Commission was also born. In 1910 it decided that its work was hindered by lack of an international vocabulary and, after a long period of gestation, the first edition of this vocabulary appeared, in 1938, with definitions in French and English, and equivalent words in other languages. In it the word 'electronics' does not appear. The Commission immediately saw that a revision was essential, but the Second World War deferred any start on the revision until after 1950. The vocabulary is now to be issued in 22 sections, the first of which, (07) *Electronics*, has just appeared. The first definition is stated to be:

> Electronics (noun): That branch of science and technology which deals with the study of the phenomena of conduction of electricity in a vacuum, in a gas, and in semi-conductors, and with the utilisation of devices based on these phenomena.

You will notice that all the topics referred to in the first lecture came within the scope of the definition, which gives them a modicum of respectability and unity after all these years.

Meanwhile, with or without official definition, science and technology have progressed. I cannot trace who introduced the word, but the American journal *Electronics* appeared about 1927, the Institution of Electronics was registered in 1935, and after that the word and all its component derivations got into classifications, especially the Universal Decimal Classification, which the British Standards Institution started to publish in English after the recent War. Now the title of Electronics is placed in degree examinations, for example of the University of London, and many universities have electronics departments, for instance Southampton; but there are, of course, no degrees in electronics, and it remains a specialized part of electrical engineering.

One hundred years ago Faraday suspected that electric charge is discrete, but Maxwell later turned this down. It was Stoney, about 1874, who made a tolerable calculation of the magnitude of the charge from electrolysis and the Avogadro number. Supported by Helmholtz and Lodge, Stoney proposed the name 'electron' for the elementary unit of electric charge, but its realization and control did not come until J. J. Thomson demonstrated his discoveries just before the end of the century.

PHOTOELECTRICITY

From then onwards electron knowledge developed, culminating in Einstein's criteria in 1904 for the release of electrons from surfaces, for which he later received his Nobel Prize, 'irrespective of the value to be attached to his theory

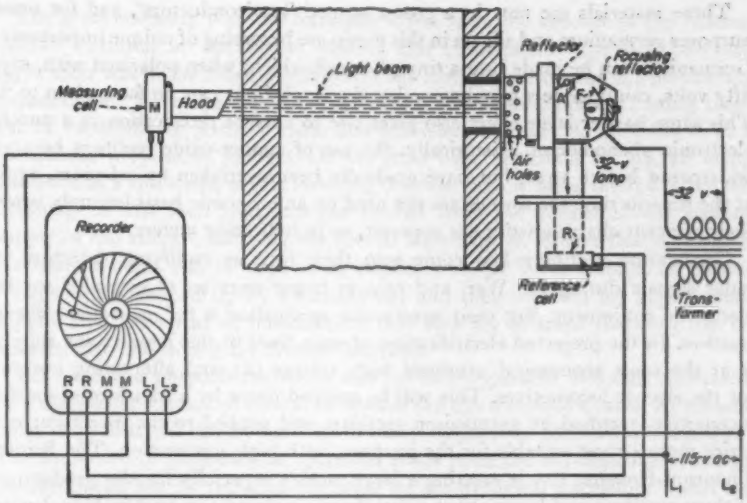
of relativity if this should be proved'. He showed that a sufficiently large *quantum* of energy is required, itself having a magnitude proportional to frequency, for an electron to leave its shell and overcome the forces caused by its release to get away from its nucleus and become free.

The easiest release is from surfaces having a low *work function* (measured in volts), such as the alkali metals, especially cæsium, and this is facilitated by enclosing the surfaces in a vacuum, with a glass or quartz window to let in the radiation. The electrons so released by the incidence of light would collect near the surface and soon suffice to reverse later emission, so they are removed by a positive voltage, about ninety volts in practice, applied to another electrode in the space. Thus, this electrode takes a current which is correlated with the incident light and so the device is a photocell. If there is some residual gas, this is ionized by the electrons released, and the augmented electrons increase the current flow and so make the device more effective as a photocell. There is some delay in the positive charges in the ionization becoming neutralized, and this leads to a dropping off in response as the frequency of fluctuation of the incident light increases. By adjustment of the gas pressure a very reliable and useful photocell results, as is evidenced in every projector in every cinema for the past thirty years; it is only within the past few years that the extant photographic sound-track in sound-film has been challenged and replaced in the more lavish films by magnetic recording.

But photocells are not confined to cinematograph sound reproduction; they are used for a bewildering number of applications in science, for instance, measurement of photographed *spectra*, and in industry, for example, for counting articles on a belt, for protecting machines and humans from faulty operations, for burglar alarms, smoke detectors, colour matchers, print registration.

ATMOSPHERIC POLLUTION

There has been much interest during recent years in smoke and consequent, though fortunately rare, 'smog'. The latter arises when a temperature inversion layer contains water droplets, which catch the smoke particles, sulphurous oxides and benz-pyrene, and which, when overloaded, come down to annoy us. Without the weight of the smoke particles, which is largely unburnt carbon, and hence valuable, we might escape smog, and it is the photocell which can guide the stoker of the boiler in doing his best to keep a fire clean. A little more than a year ago there was a mass-survey of the content of smog on two occasions in London and Manchester by members of the Civil Defence, organized by Dr. Booth of the Fuel Research Station of the Department of Scientific and Industrial Research. Sufficient information was obtained to establish artificial smogs, so that experiments can be made on their control. There are smokeless zones in Manchester and London, but however well-trained a stoker may be he must have precise indications from a meter to guide him, especially if he cannot see the smoke from his own stack, which is usually the case. The domestic fire must take a considerable share of the blame for atmosphere pollution, because it is impossible to control so many small sources. Potential shortages



[By courtesy of Radiovisor Ltd.

FIGURE 7. *General arrangement for detecting, measuring, and recording smoke density*

of soft coal may assist propaganda for alternative sources of heat; if the national interest is the sole criterion, all low-grade heating should be by gas.

A beam of light from a stabilized lamp passes through a sample of the smoke or across the chimney, and is received into a photocell. The lenses focusing the light are recessed to avoid getting too dirty, or a clean air blast is injected to keep them clean. The current from the photocell is used to give an indication on a meter and the stoker has to keep this indication within certain limits; a recorder may also be fitted. The scale is marked off in Ringelmann units, which are somewhat crude and date from 1890, but form a useful scale for this purpose; there is no technical virtue in having a scale more finely divided than is necessary. Power-stations have their own schemes for washing the dirt out of the flue gases and produce little pollution in relation to the coal or oil consumed.

SEMICONDUCTORS

There are other types of photocell. The selenium cell is of historical interest, because of its use in magnifying cable telegraph signals and its use in the first sound-film reproduction by De Forest. In films of some allotropic forms of selenium the electrical resistance changes with incidence of light. Such cells have been replaced by barrier-type cells, in which there is a differential effect between surfaces of, for instance, selenium or copper oxide on iron, when the interface is illuminated. Such cells are useful in many applications where a high voltage supply must be obviated, such as a day/night switch on a harbour buoy.

These materials are now in a group termed 'semiconductors', and for some purposes germanium and silicon in this group are becoming of unique importance. Germanium can be made into a tiny photocell which, when polarized with, say, fifty volts, can operate a telephone relay if enough light can be focused on to it. This same barrier layer effect also gives rise to current rectification as a purely electronic phenomenon. Historically, the use of copper-oxide rectifiers became widespread before 1930, but have gradually been overtaken by selenium, until at the present time the former are not used on an economic basis but only when their relevant characteristics are superior, as in indicating meters.

Germanium rectifiers had come into their own as rectifying detectors of radar signals during the War, and now in larger sizes are of extended use in electronic equipment. But their spectacular application is for main-line railway traction. In the projected electrification of main lines in this country the supply is at the most economical overhead high voltage (25,000) alternating current for the electric locomotives. This will be stepped down by a transformer on the locomotive, rectified by germanium rectifiers and applied to the direct current series motors most suitable for the purpose, with high acceleration. The British Thomson-Houston Co. is erecting a large factory especially for the production of these rectifiers and locomotives using them are already on trial in Manchester and the east of London. The remarkable fact of these germanium rectifiers is their very high efficiency of conversion, about 98 per cent, leading to small bulk, and long life. Silicon rectifiers promise to be equally effective and can be operated at a much higher temperature, but because of the commercial difficulties of obtaining very pure silicon in very large quantities, it may be some time before they are widely practicable. For laboratory use small silicon rectifiers are preferred because of slightly greater stability for precise measurements.

TRANSISTORS

The next step is but a few years old, that of controlling the rectifying process in a semiconductor by an additional electrode, much as the 1904 thermionic Fleming diode was changed into a vastly more important device by the introduction of the grid by de Forest in 1908. The new device using germanium, or perhaps silicon in the future, is the *transistor*. It has already made a major impact on technology as a component which can replace thermionic valves with great reduction in power requirements for operation, but has introduced possibilities peculiar to itself. Briefly, it is a tiny device which can be regarded as a current amplifier, yielding more controlled current than is required to control it, as compared with the thermionic valve, which delivers controlled power without necessarily absorbing power to perform the control. The valve requires, however, an excess of electrons from a source which is normally electrically heated, and hence requires considerable power. Moreover, to operate transistors the power supply, normally small batteries, can be but one-tenth of that essential for the operation of thermionic valves, which is of the utmost importance in portable equipment, where unlimited power supply from the mains cannot be available.

The great economy with the transistor arises from the absence of the heating current required in thermionic valves, and consequently the first practical application was in the hearing-aids where the lifetime of batteries is a paramount consideration. There have been experimental circuit developments using transistors, especially in portable radio and television, but they do not seem to be a commercial proposition just yet. On the other hand apparatus for aircraft using transitors as a space and weight reducing consideration is being offered. Here the advantage is that such apparatus can operate from the normal 28-volt battery supply of the aircraft, omitting the special high-tension. Where this is essential the transistor can also be used as an oscillator at the lower voltage, its output voltage being stepped up by a transformer and then rectified for high-tension supply. Another virtue of transistors is that they are so small that they can be inserted into the wiring for diverse functions.

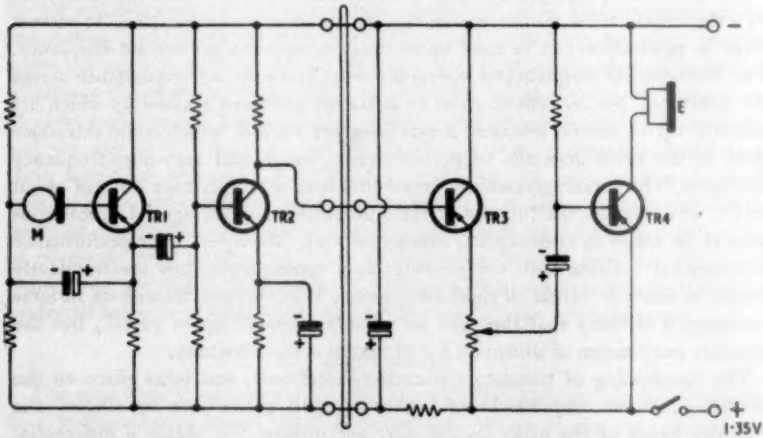
For particular purposes their gain may not be comparable with that obtainable by a thermionic valve, but several in cascade can often replace a valve. At present those in production can be used up to many megacycles per second frequency. The limitation of frequency of operation arises from the self-capacitance across the interfaces, but by reducing the areas we are promised transistors which are effective up to several hundred megacycles per second, which could introduce them to the fields generally of portable radio, radar, and very-high-frequency television. The extant germanium transistors have a temperature limit of about 70°C., which limits the full use of their properties because special precautions have to be taken to remove their dissipated heat. Moreover, their performance is somewhat variable with temperature; as a consequence they are frequently placed in holes in blocks of light alloy metal. When silicon transistors become available, it is likely that they can be reliably operated up to 120°C., but the requisite purification of silicon on a commercial scale is not easy.

The functioning of transistors is entirely electronic, and takes place on the interface between tiny blocks of highly purified germanium or silicon, the impurity being of the order of one part per million. To obtain a differential effect, a few parts in a million of another element, for instance indium, is added. In the crystal lattice of the parent metal the impurity causes a variation in the conductivity by the very small proportion of electrons from the outermost atomic shell; if it augments this conduction the material is called *n-type*, whereas if the conduction appears to be in the opposite direction, because the positive nuclei of atoms cannot move and few loose electrons move in the opposite direction, there is *hole conduction* and the material is termed *p-type*. The bulk manipulation of these tiny blocks, some only a few thousandths of an inch thick, is a triumph of manufacture which has not yet been disclosed.

A major application of transistors is to electronic computers; one of the disadvantages in the air is weight, and on the ground in offices is power dissipation, when thermionic valves are used. The pioneer computer LEO dissipates nearly thirty kW., the disposal of which causes complication. Other computers dissipate less, but transistors, if found applicable, should greatly reduce both size and heat problems in these machines.

SPECTACLE HEARING-AID

For humanitarian reasons scientific discoveries frequently find their initial usage in applied medicine. Thus crystal (piezo Rochelle salt) microphones and miniature thermionic valves quickly found their way into hearing-aids, and a range of layer-type Leclanché cells were standardized as power supply; extremely small amplifiers were developed and proved effective. But the demand for power came from the necessity for heating the filaments. In the newer subminiature valves, the heater wire is no more than 6·5 microns in diameter, about one-tenth of that of a hair, with considerable economy. But the elimination of filament heating by transistors naturally made developments with their aid desirable. This has been achieved with a reduction in power requirements from a much lower voltage, indeed one simple cell.



[*By courtesy of Bonochord Ltd.*

FIGURE 8. *Typical transistor amplifier (TR1–4) for hearing-aid, between microphone M and earphone E*

The obvious scheme is simply to replace the valves in the pocket amplifier, and this is quite effective, but a more remarkable achievement is to incorporate the components of the hearing-aid in the side-frames of spectacles, of great value when sight has to be re-focused, as well as aiding the ears. In the accompanying circuit, the crystal microphone and two of the transistors are in one side-frame, while the other contains the other two transistors, the volume-control and switch, as well as the single cell, little more than a large pea; the insert electromagnetic receiver is fed through a flexible cord. Although there is some acoustic disadvantage in that microphone and receiver are on opposite sides of the head, this also permits a high gain, free of internal noise, and no possibility of self-oscillations. The cell is a new type developed during the

recent war, using mercury as a depolarizer, and with superior discharge curves as compared with ordinary Leclanché cells.

THERMIONIC VALVES

The thermionic valve is so widespread in use that little need be said, except to deplore the multiplicity of types which engineers have to deal with. Of one type alone some hundred millions were made during the recent war, and they are in every radio and television set. These have lives of 1000-2000 hours which may be greatly exceeded, but many applications demand longer and more stable lives under arduous conditions. During the past few years valves of enhanced reliability for industrial use have appeared, culminating in those required for the amplifiers built into the cables just laid across the Atlantic; these are expected to last more than twenty years in continuous service. We do not know yet how they will be replaced; possibly a new cable will be laid while an original cable is brought up and serviced.

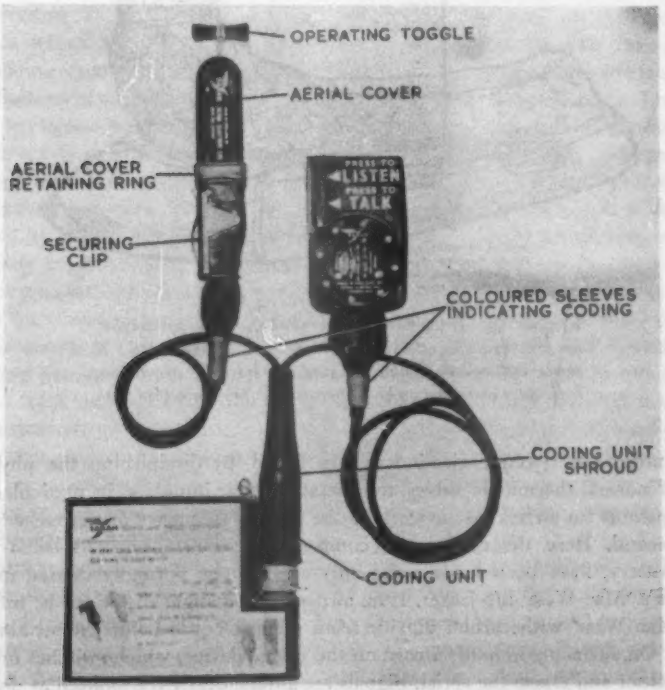


FIGURE 9. *SARAH rescue beacon. By pulling the operating toggle the aerial unwinds and the transmitter is switched on*

As the frequencies for radio communication are pushed higher and higher so is there a demand for valves to generate and control currents at these frequencies. For wartime radar purposes the magnetron and klystron were perfected. In the former electrons are emitted from a large cathode and fall on a solid circular anode in which there are resonating cavities; during their passage they are spun in loops and transfer their energy to the cavities, from which it is picked off by a loop at the start of a transmission line. In the latter the beam of electrons is bunched by passing through the centre of a ring cavity resonator; originally, the beam was debunched by a similar cavity, but the device was made stable by reflecting the beam back through the buncher; power is taken off the cavity by a loop at the start of a transmission line. The high voltage is applied in pulses to both valves, which correspondingly generate pulses of high frequency radiation.

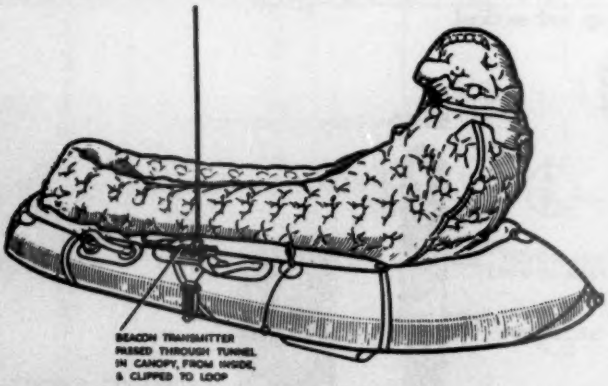


FIGURE 10. *If the pilot has an inflatable one-man dinghy, he can transfer the SARAH beacon as indicated; it sends out coded signals to guide a rescuing aeroplane, helicopter or launch, which operate on a pre-concerted plan*

At much lower frequencies it has been found, by diminishing the physical size of normal thermionic valves, to generate similar impulses, in particular for an apparatus for air/sea rescue work on the distress frequency of 243 megacycles per second. Here the equipment, comprising a transmitter, talk-listen unit and battery, have been made sufficiently small to be normally carried on an airman's 'Mae West' life-jacket. If an airman has to alight in the sea he inflates his 'Mae West' with carbon dioxide from a small bottle before he strikes the water. On surfacing he pulls a cord on the rescue device, which switches on the transmitter and erects the aerial. Signals are automatically transmitted as double pulses, the timing between the pulses identifying the transmitter according to a code as exhibited on a cathode-ray tube on the rescuing aircraft or launch.

These signals can be transmitted for more than twenty hours, and can be picked up by a high-flying search aircraft up to eighty miles away. When the rescue craft is within hearing the airman can speak to the rescuing vessel.

This equipment made its first genuine text-book rescue last July; a pilot baled out at 35,000 feet and was rescued from the North Sea with less than 200 feet visibility.

GAS-FILLED VALVES

The vacuum thermionic valve has as hard a vacuum as can be achieved, in practice by a *getter*, which has a high affinity for attenuated gas. There is still a wide scope for non-vacuum valves, the first and still widely used being the mercury-arc rectifier. Here the initial supply of electrons is thermionically emitted from the hot-spot on a pool of mercury, originated by a deliberate arc drawn by an auxiliary electrode. These electrons, attracted to a high voltage anode, ionize the residual mercury vapour, yielding a plasma of increased densities of both electrons and heavy positively-charged mercury ions. The electrons augment the current to a high density, but the mercury ions remain and slowly drop into the cathode, contributing to the actual rectifying action. Normally there are three or six anodes which steal the arc as they successively become positive during the alternating cycle, so that the arc, once struck, never goes out. The efficiency of rectification in power supplies is about 98 per cent, and many of the London tube trains are driven through these rectifiers. In the new electric locomotives which are being ordered for the development of British Railways, a large percentage will have on board mercury-arc rectifiers, in competition with the newer germanium rectifiers. For fine control of these large rectifiers a grid is added, so that by adjusting the phase of the voltage on this grid the conduction can be precisely triggered to the anode.

The smaller mercury rectifiers with grid controls are called thyratrons and are more than twenty years old. They are widely used for medium rectified power requirements and for the precision control of electric motors, for instance in printing presses. In other types the mercury is replaced by neon or other rare gases. Here the ionization is effected by a sufficiently high potential gradient at the cathode, which is cold. Thus a voltage can be made to trigger off conduction in a valve, and is sustained by a high tension supply. In conjunction with photocells these economical devices are valuable in burglar alarms, and in endless devices in industry which require the combination of reliability, economy and robustness.

A further development of these cold-cathode tubes is in a multi-anode device analogous to the mercury-arc rectifier, but on a much smaller scale. By means of an electric impulse the neon glow and conduction can be made to hop from one anode to another; in fact, using a number of anodes, generally ten, a counter can be made of the utmost utility in batch counters, cosmic-ray counters, and the like, where an immediate display is evident of the total of such impulses. A batch counter is one in which the desired number of impulses, for example

from articles on a belt, can be set and counted backwards until the required number is attained, when the belt or hopper is stopped.

Another remarkable application of a combination of such devices is the random-number-selection machine which has made the Premium Bond scheme possible. The problem is here to select more than 20,000 numbers according to a specified random formula. Although tables of such figures are available, the labour of selection would be prohibitive, so a development of the Research Station of the Post Office has been adapted so that the required numbers are printed directly every 3.5 seconds on a Creed page-printer. The basic idea is to generate a random noise by a gas-filled valve. The magnitude of the irregular waveform below the peaks is cut off, and the number of peaks in a given period of time, say, one-twentieth of a second, counted. The last figure of this count is taken as a random number. By taking nine of these channels, it is thus evident that a nine-figure random number can be easily obtained.

CATHODE-RAY TUBES AND CAMERAS

By 1925 we were getting cathode-ray tubes which were operable in laboratories at relatively low voltages, but those introduced for television now require up to seven kV. for direct viewing and up to twenty kV. for images projected on a screen. In this domestic device there is continuous development, both for life and to diminish the length for a given size of screen; efforts are directed towards getting a wider angle of deflection of the cathode-ray beam which writes out the image.

It used to be a puzzle where the electrons go when they are sprayed on the screen to excite its flourescence. Depending on their energy, electrons splash out up to eight times those incident, so consequently there is always a balance between those which arrive and those which depart. This phenomenon of secondary electron emission is the clue to understanding how television cameras work from the electronic point of view.

In the ionoscope camera the external scene is focused on to a signal plate which comprises a myriad of isolated photocells. These cells are busy losing electrons because of the incidence of light and, because they are negative, each cell unit, a little blob of silver and cæsium, charges itself to a rising positive potential. When the scanning electron beam passes over a cell and deluges it with electrons of high energy, many more are splashed out as secondary electrons and the potential rises to a saturation positive potential of a few volts while the beam is on it. When the beam has passed the cloud of secondary electrons outside the cell are immediately attracted back and the cell starts off again from a slightly negative potential, rising slowly positive through incidence of light. The *signal* representing the intensity of the *incident light* is actually the sudden rise of potential when the beam arrives. This varies because of incident light and so the signal is modulated. This action is typical of electronic behaviour.

Moreover, electrons can be focussed by electrostatic lenses, which are simply holes in discs held at suitable voltages, or twisted and focused by magnetic

lenses, which are simply iron-cored coils which are designed to give sharp curvature in magnetic fields along which the beam of electrons travel. In domestic television sets the beam deflection is usually magnetic, while in laboratory equipments, where length does not matter, the deflection of the beams is generally electrostatic.

Referring to colour television, an experimental system has been on public trial in the United States for some years, but there are additional difficulties in the introduction of a colour system in this country, apart from the cost. The clamour for television after the recent war resulted in the rehabilitation of the pre-war system, itself adequate and a pioneer, but now superseded by higher definition systems on the Continent. Because it is most desirable that television programmes should continue to be interchangeable between this country and the Continent, it follows that the colour system here should fall into line with the number of lines in the raster which will be adopted there. On the other hand, it is most important that the new colour system shall be *compatible*, that is, receivable on the present black-and-white receivers, otherwise millions of these become obsolete. There is a Television Advisory Committee, representative of all interests in this country, which is considering what can be done in making a wise choice of these two procedures. In addition, the Comité Consultatif International Radio is studying what can be done in Europe as a whole.

It has been found that the colour appreciation of our eyes can be satisfied with but one-tenth of the definition required for the appreciation of the tone values of the same picture in black and white. In fact, the television picture will be a black-and-white picture coloured by a *chrominance signal* carrying information with about one-tenth of the maximum frequency required by the black-and-white picture. This means that, using a single or vestigial video signal, the total signal, including the sound and chrominance signals, can be accommodated within the present allocation of television frequency bands. The chrominence signal is one which varies in phase and magnitude with reference to a *burst signal* at the start of each scanning line, and the information derived from this can be interpreted into the modulation of the gun which provides the scanning in the receiving tube. This is more complicated than the present television tube, the screen being covered with a regular pattern of dots, of fluorescent powders which emit rays of the primary additive colours. To achieve the correct incidence of the beam the triplicate spots are aligned with a specially perforated signal plate. Excellent television in colour has been demonstrated in this country, but no move can be made towards a public service, even if the expenditure is allowed, until a decision at the highest level is taken with respect to progress or compatibility.

Television presents a typical example of how apparatus developed for one requirement becomes useful in other fields of activity. While entertainment on a large scale prompted the development of television systems, they are now used on detailed applications in local or closed circuit systems; here there is no radiation and consequently there are considerable simplifications which bring down the cost, making it possible for day-to-day use in industry. The first

closed circuit was apparently in hospital operating theatres, where it is obvious that a considerable number of students can be provided with a close-up of operations, as compared with remote views for a limited number of students previously. Since then local television transmission has been very useful in viewing dangerous processes, looking into furnaces and remotely indicating meters to control desks, and so on. A use which attracted special public attention was the underwater identification of a sunken submarine by a television camera suspended in a waterproof tank, the reproduced pictures being observed and photographed in a ship above. Portable television sets have been demonstrated for warlike purposes and came into their own for candid camera shots at political conventions, so far only in the United States. At the last Presidential nomination meeting in Chicago there were actually more television technicians than delegates, and a vast array of portable plant to relay the 'video' signals away to the networks was installed.

ACKNOWLEDGEMENTS

During the lecture, ERNIE, the two-channel model of the random-number machine for Premium Bonds was shown by the courtesy of the Director of Research, Post Office Research Station, Dollis Hill, London.

The SARAH air/sea rescue equipment was shown by the courtesy of Messrs. Ultra Electric Limited, Western Avenue, London.

The subminiature valve heating wire, provided by Mr. R. C. Winton of Messrs. Mullard Ltd., was shown in a lantern slide in comparison with a hair.

III. PLANT

Monday, 10th December, 1956.

MATERIALS

It is not too much to say that many developments of great importance in engineering electronics owe their existence to the materials of superior and unique qualities which have been produced during the last generation and especially since the recent War. Before then the materials were mostly traditional, with steady improvements as they found application; most spectacular was the increased magnetic energy sustainable by new magnetic materials, especially Ticonal and Alcomax. The former is the choice where volume and weight are prior considerations, while the latter can be just as good with slightly greater bulk, but lower cost; both can sustain twenty times the energy of the old, but still useful, cobalt-steel magnets. For conducting magnetic flux Permendur could take double the extant for the same magnetomotive force and less leakage. Following Permalloy and Mumetal, other alloys permitted transformers at radio frequency, and when ground up and formed with a binder the losses became tolerable at television frequencies.

A development of recent years is a reversion to the old lodestone, but with a difference. One or more of the metal atoms in the molecule Fe_3O_4 is replaced by another, such as manganese, with startling results. The hysteresis loop of this ferrite now becomes rectangular and, because of non-conductivity when sintered with a binder, can be used for a very fast memory, in fact operating with megacycle per second impulses in electronic computers. Tiny rings are made of this metalloid material and many thousand are knitted together with conductors. One set of conductors can magnetize the rings in either direction, while another set take currents which can examine in which direction the previous magnetization has been left, thus recovering a pattern of signals required to be stored while other operations in the computers are being carried out.

While the wartime magnetron might have been successful with ordinary magnetic material, the large horns of Alcomax contributed markedly to its efficiency, just as ten years earlier the Olson ribbon microphone was provided with a Ticonal magnet, so obviating the battery feed to the electromagnet, and just meeting the exacting efficiency required for modern broadcasting.

Although Poulson envisaged magnetic tape when he invented magnetic recording on steel wire just before 1900, it was not perfected until just before the recent War, when the Germans wanted a temporary recording to interpose a delay for censorship in broadcasting. After the War when these recorders were brought to this country, development of magnetic tape accelerated and is now available in vast quantities, of such a quality of reproduction that practically all disk recordings are simultaneously recorded on tape, as commercial safeguards, and also, within the past year, as the basis of domestic tape recordings in their own right. Such tapes have recently invaded the office for dictaphone

purposes, abolishing the old wax cylinders, while a rapidly increasing number of home recordists are building up an industry to cater for their requirements.

Allied with electronics is the gramophone disk, which is purchased by the public in hundreds of millions every year. Since the War there have been great efforts to supersede the extant 78 r.p.m. disk with a disk which plays much longer, and the new speed of $33\frac{1}{3}$ r.p.m. was re-selected as being most suitable, a relic of the earlier sound-films when the sound accompaniment of the Vitaphone system was on large disks. The reason why the long-playing disk is possible resides in the material of the disk, vinylite, which has so small a grain, which causes the background noise, that a new compromise is possible between the fineness of the groove and the length of play. From a different angle there has unfortunately been introduced another speed, 45 r.p.m., so that the real enthusiast has to have a triple-speed turntable to play all his records. The direct-recording and reproducing disk, invented by Watts about 1928, is still produced in very large quantities, the British Broadcasting Corporation using for its own purposes some thousands per week; such transcription records can be processed and made into ordinary gramophone records if required.

The most important intrinsic new development of magnetic recording is for the wider films used for sound-film in cinemas during the past few years. There has been a demand for stereophony, which gives a spatial radiation of sound to correspond to the more widely dispersed apparent sources of sound emanating from the screen. These multiple sources were originally photographically reproduced from a separate film, as in *Fantasia* (but not as shown in this country), but now arise from magnetic powder stripes on the photographic film itself. In one new standard there is not only the wide picture to be projected and the two sets of sprocket holes to make the film progress through the projector, but also no less than four magnetic sound-tracks, all within the 35 mm standard width of film. For amateurs it is possible to have a magnetic sound track striped on to a finished film, the recording being done afterwards as a commentary or as dubbing.

For capacitors there have been several developments. Piezo crystal materials, including barium titanate, have a very high specific inductive capacitance when polarized, and this enables tiny ceramic capacitors to be constructed in a very small space, especially useful when smoothing or blocking of circuits is required. The aluminium has been replaced in some instances by tantalum foil, while a polystyrene film as dielectric has shown the possibility of storing charges in capacitors for years without appreciable leakage.

In the radar field there might have been some difficulty in transmitting the power generated by the magnetrons and klystrons had not polyethylene been developed as a superior insulator of cables, with a remarkable drop in its dielectric loss at the very high frequencies required. A new competitor for low-loss was found in polytetrafluoroethylene, PTFE for short, which at 1000 megacycles per second has a dielectric loss one-fifth of that of polyethylene; unfortunately, it is not flexible. Its preparation from pellets is by compression in moulds and sintering under a moderate temperature for an hour or so. It can be finely machined

and has a remarkably low coefficient of friction, which makes it (to the regret of the electronic engineer) of unique value in certain ranges of mechanical bearings, where it can take a heavy loading. It cannot be flowed or stuck to anything, but it can be shaved into a very thin tape. Its steady D.C. resistance is higher than anything else known and it is possibly the only material for insulators for ionization apparatus. It is better than sulphur for this purpose and also repels moisture and oils.

It has a mechanical memory. If a form is sintered in a mould without much pressure and is then heated with more pressure, say one ton per square inch, it contracts and retains the form if cooled under pressure. If it is heated again without pressure it expands to the original form.

UNIT OF TIME

The piezo properties of perfect quartz crystals are still extremely important in that thousands of such carefully-cut crystals are used in the filters for the multi-telephone circuits now being installed since the mid-'thirties for large telephone extensions. Practically every radio transmitter is controlled by a quartz thermionic oscillator, and precision of its time-keeping has led to considerable plants for international checking of time and radio frequencies.

As a consequence of this precision the international definition and realization of our unit of time, the second, has recently been changed. For a long time it was the duty of a vacuum pendulum at Greenwich Observatory to divide the mean solar day into 86,400 equal parts. After the First World War it was shown by Pierce that the frequency of thermionic valve oscillators could be stabilized to high precision by coupling them to tiny slabs of quartz crystal. It appeared, after long trials, using groups of such quartz-crystal oscillators, that the tides in the Thames affected the Greenwich pendulum, so the latter was replaced by a group of such oscillators. These are so precise in their timekeeping that the daily rotation of the earth is now inadequate as a basic standard of time, and it has just been decided internationally that quartz-crystal oscillators are to divide the mean tropical year instead of the day into the requisite number of seconds.

ELECTRONIC CONTROL IN PROCESS PLANTS

There are several directions in which electronics is making itself felt in industry. Taking the simplest as the direct control of flow or heat as directed by detecting elements, such as temperature, pressure, or especially hydrogen ion potential, the total of such controls in a chemical process plant can be impressive. In a large refinery or chemical plant, it is now quite usual to have the whole plant directed from a control table by one man, surrounded by his meters and recorders. Many of the actions he might be considered to make in controlling the plant are taken out of his hands, because he just cannot act quickly enough, even if he could grasp exactly what to do in certain circumstances. Another feature is that the multiplicity of recording data from meters is now no longer provided for, or considered essential; in fact, the reverse attitude is taken. When a plant

is set up and put into operation, the various meters have to indicate the steady conditions within certain limits; if indicating outside these limits, action is called for. So the attention of the operator is called only when there is an imminent danger of a meter indicating outside the normal operating limits. Likewise it is necessary to record only such data and the time of occurrence.

ELECTRONIC MACHINE CONTROL

In another direction is the electronic control of machine tools in factories. So far it has been found worthwhile to attempt control on high-grade tools making precision parts, expensive machine tools which should be kept working continuously and not held out of production during the many periods when the operator, himself a skilled man, has stopped the machine and is pondering what to do next. Two systems have been developed in this country for complete control of a machine tool, apart from such applications as keeping the cutting speed constant on a lathe, so as to keep up a high average output.

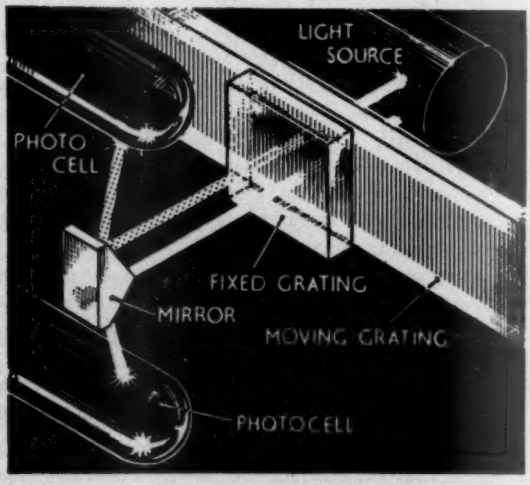
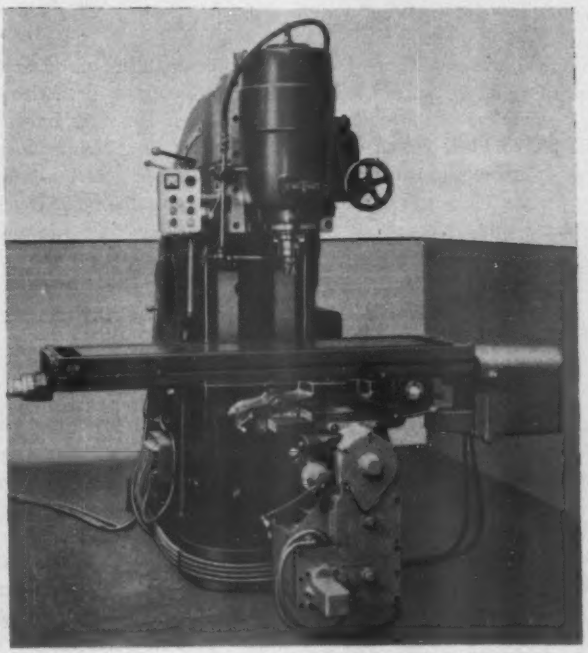


FIGURE 11. *Diagramatic illustration of the Ferranti system of machine control, using optical gratings to generate photocell impulses as a measurement of movement*

In the Ferranti system, the basic idea is so to design the parts that their dimensions can be expressed as coordinates in a table, and these coordinates can then be punched on to paper tape; then put into an electronic computer, which automatically works out the intervening points in terms of ten-thousandths of an inch, which is better than any tolerance required in the machining operations. This data is then recorded on one or more magnetic tapes, which are used to operate the actual machine or machines, depending on

the output required. In principle the tape tells the controlling mechanism how many thousandths of an inch the table holding the workpiece has to move. Attached to this table is an optical grating with 5000 lines to the inch, facing a similar fixed grating, a beam of light passing through both into a photoelectric cell. The number of interruptions of the light as the table moves with the work-piece is then counted back until the required total is obtained. When this is done, another part of the motion can be undertaken under control. It is found that there is some advantage in having a split beam and a push-pull photoelectric system. In the Electric and Musical Industries system the input coding is slightly different from the Ferranti which uses normal punched paper tape, punched with a modified Creed perforator. In the E.M.I. system there is a group of four groups of possible holes, which can represent a four-figure number, on a binary scale. This is fed into the electronic computer, which includes an electric interpolating device which takes the form of an electrical analogue to a cubic or quartic equation, deducing the interpolating points intended to be positioned by servo motors which drive the table carrying the work piece.



[By courtesy of Electric and Musical Industries Ltd.

FIGURE 12. *An elaborate machine tool entirely controlled by tapes and an electronic computor. The motions of the work-piece on the table are controlled to serve on the right, including inter-polations required between points specified at intervals on a curve*

Whenever there is a complicated mechanical set-up, as in an automation plant of transfer machines where the castings are passed from one station to another with the mechanical operations of drilling, boring, and so on, each being automatic with mechanical control, there is ample scope for timing and integrating these transfers and storage with electronic equipment of no great complexity. Indeed there is little more intrinsic complication than is met in the multifarious controls of feeds, countings, valve openings, timings, and level-controls already well used in industry and likely to be further used, limited only by confidence in the actual equipment.

There is under development in this country a large feeding plant for a car mass-production assembly system. Here it is essential that the components fed to the line from side conveyers arrive at the correct time and are also correct in themselves. This is an ideal application of electronic devices, because it is quite simple to have master cards or tapes which hold the required coded information and to use these to operate the selection and feeding of the components required day by day for the production.

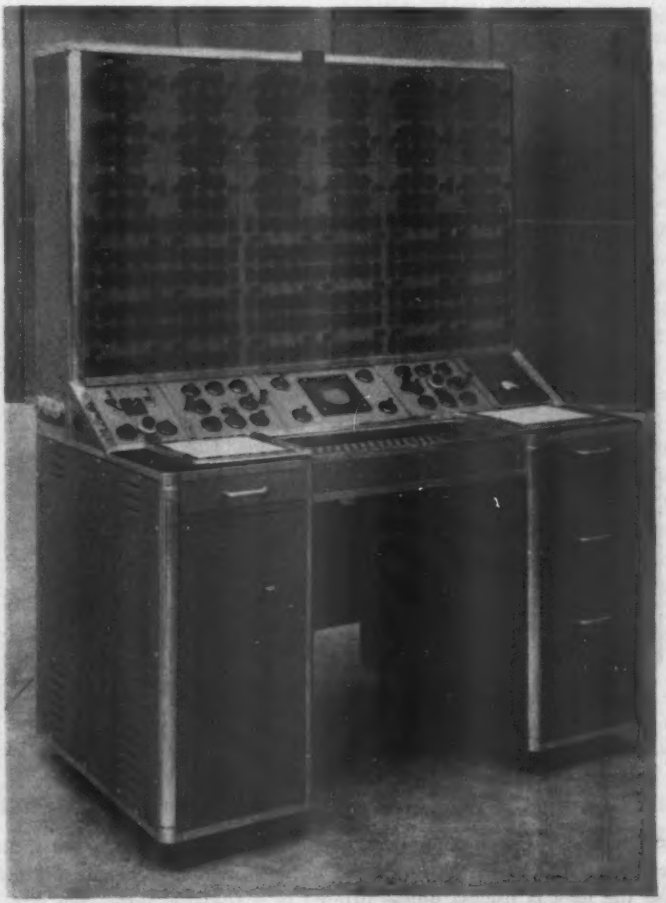
ELECTRONIC COMPUTING

In the field of actual complete electronic computing there are two main divisions, those of *digital* and *analogue*. Taking the latter first, this means that there is a functional relation between one variable and another, but it is generally impracticable to make actual calculations because of the difficulties from the economic or manpower situation. A general purpose analogue computer has been put on the market (Figure 13). It has a large number of integrating and differentiating units as well as amplifiers of various kinds, so that currents analogous to the variables in equations can be simulated and answers obtained quickly. At the Royal Aircraft Establishment, Farnborough, there is an enormous analogue computer for aerodynamical computation, bearing out the view that such analogue computers have generally to be built to do restricted types of calculations.

Digital computers are more versatile over particular fields, and find their present main application in office work, where the money that has to be dealt with, or the articles of which stock records have to be kept, are discrete and can be counted exactly. The digital computer therefore operates on impulses, and the impulses are generally coded on tape, which is fed into the machine, originally with a Creed telegraph teleprinter, since these have been available for nearly half a century, but more recently by reproducing the holes photoelectrically. In the Ferranti reader light is passed through the holes in the perforated tape and are received into five or seven photoelectric cells, which can read 200 sets per second and hold the last one by a clutch operated electronically, or 400 per second if there are spaces on the tape. These signals are called into the machine when it is ready to receive them.

Before operations the machine is set by a *programme*, which is a tape or card on which are recorded the signals which are stored in the machine and which

direct its operations on the data presented. Thus the programme may be for some thousands of employees' payroll, the machine doing all the requisite calculations of income tax, bonuses, club subscriptions and the like, printing out the answer at the rate of some three employees per second. This is one of the large operations that was perfected by the pioneer in this country, LEO, as constructed by Messrs. Lyons Ltd., at Cadby Hall.



[By courtesy of Short Brothers & Harland, Belfast

FIGURE 13. *General-purpose analogue computer. The magnitudes are set up by the various knobs on the vertical units, while the arrangement of the circuits is set up on a plug board under the flat in front of a cathode-ray display*

Because digital computers are entirely operated through valve circuits, great attention has to be paid to this device, because experience has shown that it is most vulnerable to breakdown. Experience has also shown that this hazard can be reduced to a negligible quantity, by the careful testing of the valves as received, giving them a bump or vibration test, and then ageing them for 100 hours before holding them for use. Likewise through general strict maintenance of all parts of the computer, the total breakdowns are reported as much less than one hour per week, and then all are very quickly cleared, which is no mean feat when the system depends on some 3000 valves.

[*By courtesy of English Electric Co., Ltd., London*

FIGURE 14. *The Deuce electronic computor. On the left is the punched card input; on the right the punched card output, with the power supply behind. At the centre control table the operator can monitor all operations on the cathode-ray displays*

The limitation of such computers, and there are now some larger and some smaller than LEO, is in the input and output circuits, especially the outputs because the data is useless unless printed in a readable form. We now have high-speed printers which print 400 lines a minute, each line having up to 100 characters, which makes it some 2000 times faster than a Creed teleprinter, which was of course developed to respond, at a distance, to hand-typing. We are promised printing at 900 lines per minute in the near future.

ELECTRONIC MEMORIES

Having dealt with the input and outputs, the capacity of the computer depends largely on its *stores* or memories. The original memories were mercury delay lines, in which trains of impulses are sent by a piezo crystal and detected at the other end by a similar device; when amplified and re-shaped these impulses are sent round again, possibly a million in series. They are 'gated' in and out with amplifiers, all the timing being locked to a clock circuit, so that nothing can get out of step. LEO has quite a large bank of long and short mercury delay lines; the long ones are for the main data to be processed and the smaller or fast stores for that required to be available immediately before such processing. In addition, there are accumulators, which add totals for subsequent printing when required by the programme.

In some applications there has to be a vast store of information, for example, in insurance work, where to be useful all the data of a policy must be available within a very short time, minutes at the most. Now a mile of broad magnetic tape can accommodate all the information on a million punched cards, but just as it takes time to find that particular piece of information on the desired card, so it takes several minutes to find it by running through the tape. One insurance firm has 25 million cards. Another difficulty is the frequent changes of address. A small insurance firm may have a million cards and the changes of address average some 25 per cent *per annum*; one firm reported eighty per cent changes *per annum*! And all these have to be recorded in place of existing information. There is, therefore, a demand for a larger memory and this has been met by using a pile of spaced magnetic disks all on an axis and rotating at 1,200 r.p.m. In a fraction of a second an arm with a magnetic head can swing in and select or record information on a desired track and so provide this 'random access' (Figure 15).

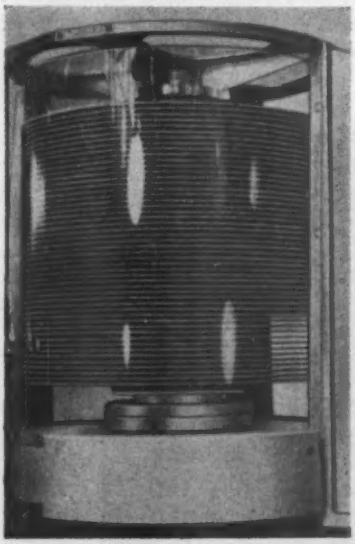


FIGURE 15. *New type of memory being developed by the International Business Machines Corp. The fifty magnetic disks rotate at 1,200 r.p.m., and are spaced 0.3 inches. Each has 100 tracks, and a double magnetic head swings in to record or reproduce from any track in a fraction of a second, thus providing rapid random access to some 5 million characters*

Another form of memory is the rotating drum or disk, both of which have been widely used. A more recent fast memory is the magnetostriction transmission of impulse signals along a nickel wire. This form of delay is very useful in

making computers out of fundamental components, which can be inserted and interchanged at will or on breakdown.

RELIABILITY

It must not be thought that electronic computers are liable to more defects than most other complicated pieces of apparatus. They are inevitably complicated and allowance must be made for this fact, both in design, manufacture and maintenance. It is the designer's problem so to arrange his components that if there is a breakdown this reveals itself in the most definite terms in the minimum time, and in bringing the machine to a halt the information or the calculations thereon are not lost, or at least can be quickly repeated or recovered with the fault corrected. The makers of LEO have made available much useful information in the respect of testing. Specific programmes are put through the machine for test purposes every day, so designed to test the validity of the equipment in every detail, much as a routiner in an automatic telephone exchange. Moreover, it has been found possible to anticipate potential breakdown by artificially degrading the performance of the valves by temporarily altering the grid bias, which at once reveals where trouble is likely to arise if steps are not taken during routine maintenance to obviate it.

FIGURE 16. *Method of changing circuits with a pointed circuit card, the conductors being left when a photo image is etched away from the metal surface of a laminate*

Not only has the electronic computer put a potential end to the vast quantity of routine calculations hitherto performed by clerks in offices, but it has led to a new profession, that of programmer, which is a very suitable outlet for mathematically inclined young people. There are numerous courses being held to prepare them for this work. There are some electronic computers being installed, but if progress seems slow in comparison with mechanization and automation in industry, it must be remembered that electronic computing is likely to bring a revolution, not only in the fact that routine work is to be done more economically, but it will have to be done in different ways. Thus it takes some time to work out potential programmes which are both possible and at the same time satisfy accountants with regard to validity and reliability. Accountants always want to know what the totals are to be before the masses of actual calculations are put in hand, so that there is a complete check without possibility of error.

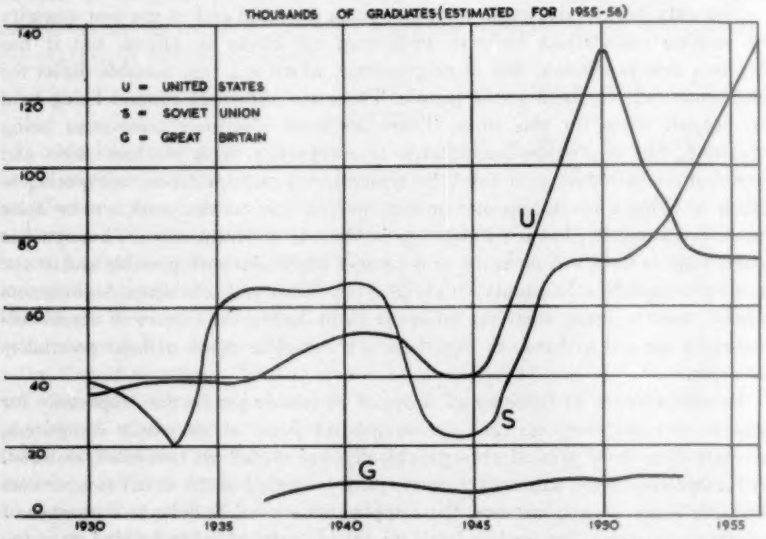
In recent years, to facilitate all forms of electronic production, especially for panels in radio receivers and the component parts of electronic computers, circuits have been printed photographically and etched on laminated material. A further step is the automatic insertion and soldering of the detail components on such bases; in one instance, the components are fed in belts to a number of machines in series, the card or laminate already printed being handed on automatically between operations.

FUTURE

One can fairly claim that the processes of the world are being altered materially by electronic devices, from the computers which are to run the routine work in offices, to the computers which will be necessary in fighter aircraft to act on data more quickly than any pilot can. We already have automatic pilots on large aircraft, but apart from ancilliary devices, such as gyro-compasses, there is at present little entire dependence on electronic devices for the control of man-carrying aircraft. With guided missiles it is, of course, quite different and beyond our present scope.

We can increasingly expect greater inroads into industry of electronic devices and controls, but where, you may ask, are the personnel, who are to make this apparatus and to see that it functions correctly and economically, to come from? There is a call from all sections of scientific research and development for more recruits, most of it unfortunately for warlike purposes. If this demand diminishes, there may be released vast numbers who can devote their energies to more peaceful aspects of those factors which in this country, which needs manufactures for exports intensely, make for improved production all round. Perhaps electronics itself, by taking the humdrum and routine aspects out of production, will release its own personnel in sufficient numbers to play its part.

Electronics is very scientific and the creative aspects require education at university or high technical college level. Can electronics ask for more than its present share of those qualified in science and its applications? In this country we have been startled by our apparently bad showing *per capita* in comparison



[*By Courtesy of Dr. R. C. G. Williams*

FIGURE 17. *Totals of scientist and engineer graduates from colleges of university rank, indicating how the Soviet Union has passed the peak of the United States following the recent War. Future prosperity depends on the production of new ideas and developments for manufactures, as well as on the consumption of electrical power*

with the United States and Soviet Russia, where technical progress may outstrip ours by compensating with mere numbers what we have hitherto achieved with brains. (See Figure 17). Our future in the world depends largely on technical progress and no obstacles should be allowed to hinder any one with a technical bent from exercising it to the full. It is unlikely that the humanities will suffer, because they do not depend on mere numbers. The greatest influence here is with the writers, and it requires only ten-thousand authors to write ten-thousand books a year, whereas it takes hundreds of thousands to maintain a simple industry. Progress cannot be controlled in a modern world, but we can play our part by regarding our share to be a duty; if this is neglected we shall fall behind in both the intellectual and material races.

ACKNOWLEDGEMENTS

The author wishes to acknowledge slides and other information provided by Dr. R. C. G. Williams, Chief Engineer of Messrs. Philips Electrical Ltd., London. Full references for all the above topics will be included in *Electronic Engineer's Reference Book* edited by the author, and to be published by Messrs. Heywood & Co., Ltd., in the autumn of 1957.

GENERAL NOTES

ENGINEERING SCHOLARSHIPS

Scholarships and prizes are offered jointly by the Junior Institution of Engineers and the Maudslay Society, to assist young engineers in their technical education and practical training. Maudslay Scholarships, any one of which will not exceed £400, may be expended on fees or for travelling to visit engineering works or educational establishments abroad. Unsuccessful applicants for the scholarships may be awarded Maudslay Prizes of a maximum value of £50. Candidates must be under 28 years of age on 30th March, 1957, which is the closing date for applications; these should be sent to: The Secretary, The Junior Institution of Engineers, Pepys House, 14 Rochester Row, London, S.W.1, from whom full particulars of conditions of entry are obtainable.

FROM THE JOURNAL OF 1857

VOLUME V. 13*th February*, 1857

ORIGIN OF STREET TRAMWAYS

From a paper On the Application of Rails for Horse Transit in the Streets and Environs of London, and also for Railway Branches, by W. Bridges Adams.

The American railways, it is well known, were made to run to and through towns and cities, instead of to them only. The inhabitants were rarely anxious, as in England to keep the rail away from them, but the contrary. It was deemed necessary to run round street corners. The first engine was ordered in England . . . with the requirement of going round a sharp curve. It was, therefore, constructed as a two-wheel engine, with a swivelling truck on four low wheels in front. This kind of truck . . . was known under the euphonius name of 'bogy'. The engine was, therefore, shipped and invoiced as a bogy-engine. From that sprung up the whole race of American bogy-engines and carriages upon two bogies. . . .

When the first railways began to work, the town authorities stipulated that the engines should be unhooked, and horses used to draw the trains through the streets; though subsequently this was compounded for by working the engine slowly, under a large maple slab, on which was painted: 'Look out for the engine when the bell rings'.

Once familiarised with railway carriages drawn by horses, the observant American mind was not slow to perceive that the arrangement was very superior to omnibuses for town transit. Street after street in New York and other cities was laid down with rails, and on streets of great traffic many lines of rails were laid down side by side . . .

A Frenchman imported the plan to Paris, and it is probable that it will become a universal Continental practice.

But it has not been done in England, not done in London, in Manchester, or other great towns, where the amount of traffic seems imperatively to call for the introduction of the system. Why has it not been done?

The answer is plain. The whole thing is so simple and easy, and the outlay needed so small, that there is no scope for either lawyers or engineers. There are neither bridges nor works to execute, nor, if managed rightly, any Act of Parliament to obtain, and no large number of persons to be interested.

Some Activities of Other Societies and Orgnizations

MEETINGS

SAT. 16 FEB. Horniman Museum, London Road, S.E.23. 3.30 p.m. F. Cheng-Wu and Miss C. Chien-Ying : *The technique of Chinese painting.*

MON. 18 FEB. Imperial Institute, S.W.7. 5.45 p.m. Mrs. L. Casinader : *Man on the spot—Ceylon.*
Metals, Institute of, at the University, St. George's Square, Sheffield, 1. 7.30 p.m. Dr. W. M. Lomer : *Radiation damage to metals.*
Modular Society, at the Royal Society of Arts, W.C.2. 7.30 p.m. W. T. Brown : *Modern architecture in the U.S.A.*
Road Transport Engineers, Institute of, at the North British Hotel, Edinburgh. 7.30 p.m. A. G. Slee and W. K. Cox : *Exhaust brake design and operation.*

TUES. 19 FEB. British Architects, Royal Institute of, 66 Portland Place, W.1. 6 p.m. Dr. N. Pevsner : *William Morris and architecture.*
Chatham House, 10 St. James's Square, S.W.1. 1.30 p.m. Sir Sydney Caine : *Self-Government and problems of personnel.*
Chemical Engineering Group, at the Midlands Institute, Paradise Street, Birmingham. 5.30 p.m. C. M. Nicholls : *Some aspects of atomic energy.*
Industrial Transport Association, at the Royal Society of Arts, W.C.2. 6.30 p.m. F. A. Paine : *Current research in packaging.*

WED. 20 FEB. Folk-lore Society, at the University College, Gower Street, W.C.1. 7.30 p.m. D. Galloway : *Transylvanian superstitions including fertility-magic weddings.*
Kinematograph Society, British, at the Royal Society of Arts, W.C.2. 7.15 p.m. H. W. Hastings : *Oil burners.*
Locomotive Engineers, Institution of, at 1 Birdcage Walk, S.W.1. 5.30 p.m. A. J. Parsons and J. S. Hancock : *Some aspects of locomotive boiler feed-water treatment.*
Numismatic Society, Royal, at Burlington House, W.1. 5.30 p.m. Dr. J. P. C. Kent : *The pattern of bronze coinage in the reign of Constantine the Great.*
Physical Society, at the Imperial College, S.W.7. 3.30 p.m. M. H. Wilson : *Goethe's experiments on colour.*
Radio Engineers, British Institution of, at the College of Technology, Cathays Park, Cardiff. 6.30 p.m. E. W. Pulsford : *Radioactivity and its measurement.*
University of London, Senate House, Malet Street, W.C.1. 5.30 p.m. D. Cooper : *Cubist painting.*
Victoria and Albert Museum, S.W.7. 6.15 p.m. Prince F. Z. S. Wittgenstein : *The castles of Ludwig II of Bavaria.*

THURS. 21 FEB. Building Centre, 26 Store Street, W.C.1. 6 p.m. J. Eastwick-Field and D. Tabraham : *Light fittings.*
Chadwick Trust, at 90 Buckingham Palace Road, S.W.1. 5.30 p.m. M. H. Thomas : *The advantages of modular co-ordination in building.*
Chemical Engineers, Institution of, at the Royal Institution, Albemarle Street, W.1. 5.30 p.m. R. Spence and C. M. Nicholls : *The processing of nuclear reactor fuels.*
Road Transport Engineers, Institute of, (1) at the Royal Society of Arts, W.C.2. 6.30 p.m. A. G. Slee and W. K. Cox : *Exhaust brake design and operation ;* (2) at the Great Northern Hotel, Wellington Street, Leeds, 1. 7.30 p.m. H. Clements : *The ability to stop.*
Royal Society, Burlington House, W.1. 10.30 p.m. Discussion : *Work-hardening and fatigue of metals.*

FRI. 22 FEB. Analytical Chemistry, Society for, at the Central Station Hotel, Glasgow. 7.15 p.m. Dr. R. Belcher : *Some recent developments in analytical chemistry.*
Applied Biologists, Association of, at the British Museum (Natural History), Cromwell Road, S.W.7. 10.45 a.m. Symposium : *The influence of light on plant growth.*
Engineers, Junior Institution of, 14 Rochester Row, S.W.1. 7 p.m. N. J. King : *Soapmaking and finishing plant.*
Mechanical Engineers, Institution of, 1 Birdcage Walk, S.W.1. 6 p.m. D. W. Rudorff : *Principles and applications of spark machining.*
Photographic Society, Royal, 16 Princes Gate, S.W.7. 7 p.m. J. Huntley : *Music and the sound track.*
Royal Institution, 21 Albemarle Street, W.1. 9 p.m. S. Robinson : *Is a conductor really necessary ?*

SAT. 23 FEB. Horniman Museum, London Road, S.E.23. 3.30 p.m. K. E. Larsson : *A Swedish fishing community.*

MON. 25 FEB. Imperial Institute, S.W.7. 5.45 p.m. Mrs. M. Rogers : *Man on the spot—Mauritius.*
Mechanical Engineers, Institution of, at the Institution of Civil Engineers, Great George Street, S.W.1. 5.30 p.m. Discussion : *Engineering education in the U.S.S.R.*

TUES. 26 FEB. Chatham House, 10 St. James's Square, S.W.1. 1.30 p.m. P. Bareau , R. Bird, and A. Shonfield : *India's second five-year plan.*
Road Transport Engineers, Institute of, at the Three Tuns Hotel, Durham City. 7 p.m. E. N. Farrar : *Two-way radio as an aid to the control of goods and passenger vehicles.*

WED. 27 FEB. Electrical Engineers, Institution of, Savoy Place, W.C.1. 5.30 p.m. E. T. Norris : *Mechanical strength of power transformers in service.*
Fuel, Institute of, at the Institution of Civil Engineers, Great George Street, S.W.1. 5.30 p.m. B. J. Burton and J. R. Joyce : *Measurements of size droplets from convergent-divergent nozzles used in oil burners for steel furnaces.*
Metallurgical Society, at the Central Library, Manchester. 6.30 p.m. A. D. LeClaire : *Mechanism of diffusion.*
Petroleum, Institute of, at 26 Portland Place, W.1. 6 p.m. I. Wells : *Atomic energy.*
Photographic Society, Royal, 16 Princes Gate, S.W.7. 7 p.m. S. W. Bowler : *Accessory apparatus construction.*
Radio Engineers, British Institution of, at the London School of Hygiene, Keppel Street, Gower Street, W.C.1. 6.30 p.m. E. W. Pulsford and N. Veall : *Some applications of nucleonics in medicine.*
Victoria and Albert Museum, S.W.7. 6.15 p.m. Sir Kenneth Clark : *Raphael and the classical tradition.*
Wool Education Society, at the Royal Society of Arts, W.C.2. 7 p.m. Dr. C. B. Stevens : *Colour in wool fabrics.*

THURS. 28 FEB. Chemical Society, Burlington House, W.1. 7.30 p.m. Dr. Long : *Application of acidity functions to the mechanisms of acid catalyzed reactions.*
Engineering Designers, Institution of, 38 Portland Place, W.1. 6.45 p.m. Dr. D. F. Galloway : *The practical application of production engineering research.*
Textile Institute, at the Carpet Trades, Ltd., Mill Street, Kidderminster, Worcs. 7 p.m. P. Reilly : *Changing tastes in design.*

FRI. 1 MAR. Cosmetic Chemists, Society of, at the Royal Society of Arts, W.C.2. 7.30 p.m. Dr. T. R. E. Kressman : *Ion exchange resins.*
Royal Institution, 21 Albemarle Street, W.1. 9 p.m. H. B. D. Kettlewell : *Industrial melanism in moths and its contribution to our knowledge of evolution.*
Textile Institute, at the Victoria Technical Institute, Trowbridge, Wilts. 7.15 p.m. E. Atherton : *Colour and colour measurement.*

SAT. 2 MAR. Horniman Museum, London Road, S.E.23. 3.30 p.m. Mrs. E. Ettlinger : *Celtic folklore and scenery.*

OTHER ACTIVITIES

NOW UNTIL 23 FEB. Charing Cross Underground Ticket Hall, W.C.2. Exhibition : *The scientist at your hearth.*

NOW UNTIL 23 FEB. Crafts Centre of Great Britain, 16-17 Hay Hill, W.1. Exhibition : *Silver and engraved glass with lithographs by the Senefelder Club.*

NOW UNTIL 24 FEB. Imperial Institute, S.W.7. Exhibition : *Paintings from Rhodesia and Nyasaland.*

NOW UNTIL 24 FEB. Science Museum, S.W.7. Special Exhibition : *300 years of pendulum clocks.*